

# The indigenous vascular flora of the forest domain of Anela (Sardinia, Italy)

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## Abstract

The importance of mountains for plant diversity and richness is underestimated, particularly when transition zones between different bioclimates are present along altitudinal gradients. Here we present the first floristic data for a mountain area in the island of Sardinia (Italy), which exhibits Mediterranean bioclimates at the bottom and temperate bioclimate at the top. We discovered a very high floristic richness, despite the fact that the number of endemic taxa is not high and the number of exclusive taxa is very low. Many of the detected taxa are at their range periphery and/or ecological margin. We conclude that climate transition zones in Mediterranean mountains and especially on islands are key areas regarding plant biodiversity and should be better investigated and protected.

## Keywords

bioclimate, biodiversity, Mediterranean mountains, submediterranean, temperate

## Introduction

Mountains are a critical landscape and ecosystem; they not only provide water for the lowlands but are a source of well-being and inspiration for numerous people (Korner 2004). The green ‘coat’ of the world’s mountains is composed of specialised biota, all



nested in a great variety of microhabitats. Mountains biota are determined by a series of climatically different life zones over short elevational distances (Rahbek 1995, Korner 2000, Hemp 2002, Korner and Paulsen 2004), which often result in areas of high biodiversity of high conservation interest (Korner 2004). However, those areas are also under high threat regarding climate change, as it is expected that they experience drastic changes (Inouye 2008).

Mountain biodiversity can be studied at a multitude of scales in space, time and function (Molau 2004). Even though species richness is usually the focal component in nature conservation, genetic diversity within species is equally important. The small-scale distribution of species in the tropical Andes, as exemplified by the plant genera *Calceolaria* (Calceolariaceae) and *Bartsia* (Orobanchaceae), contrasts against the situation in high-latitude mountains, e.g. the Scandes, where species have wide ranges and many are circumpolar (Molau 2004). Several studies on alpine plants, based on molecular data, show that the intraspecific genetic diversity tends to increase with latitude, a situation brought about by glaciation cycles permitting repeated contraction-expansion episodes of species' distributions (Abbott et al. 2000, Abbott and Brochmann 2003, Gamache et al. 2003, Holderegger and Abbott 2003, Lian et al. 2003, Abbott and Comes 2004). In tropical mountains, species distributions are geographically much narrower, often as a result of relatively recent, local speciation (Deshpande et al. 2001, Friar et al. 2001, Tremetsberger et al. 2003a, 2003b, Zhou et al. 2003). Thus, the classical decrease of genetic diversity observed from the equator toward the pole can eventually be blurred for mountain species. Actually, repeated contraction-expansion of species ranges has led rear edge populations to maintain some genetic diversity, therefore counterbalancing the effect of peripheral isolation (Hampe and Petit 2005). Conjointly, the high genetic differentiation between populations underlines the conservation relevance of those populations.

Mediterranean mountains represent an interesting case, because they often have a relic temperate-like bioclimate at their top (with no or little summer drought) in a context characterised by severe water deficit for at least two consecutive months at lower altitudes. Mediterranean mountains can therefore be considered as climatic islands, where plant diversity patterns are influenced by different factors (or in different ways) with respect to temperate and boreal mountains (Winkler et al. 2016). Furthermore, climatic and land-use changes have different effects on Mediterranean vs Boreal-Temperate mountains of Europe, being detrimental for the floral richness of the first and increasing the species richness of the second (Pauli et al. 2012). Considering that expected climatic trend is an increasing of temperature and a decrease of precipitation (mainly during spring) in Mediterranean mountains, whereas non-Mediterranean European mountains will not experience a reduction of annual and spring precipitation (Bravo et al. 2008), the urgency rises to monitor those mountains at the transition between Temperate and Mediterranean bioclimates. Moreover, before the middle of the century, the expected climatic changes will provoke the disappearance or strong reduction of a suitable habitat in the summit area, where most of the endemic and/or rare species are located (Benito et al. 2011). The most endangered habitats and species



are those linked to water availability like streams, wet meadows and temporary ponds (Ghosn et al. 2010, Pérez-Luque et al. 2015). On islands, threats to mountain floras are even more acute compared to mainlands, because narrower spatial scales of habitats and the usually lower mountain altitudes (Vogiatzakis et al. 2016), led some species to have a relic distribution (Petit et al. 2005, Mayol et al. 2015, Fazan et al. 2017). Historical climatic fluctuations and associated ecological constraints are the basis of the fragmented distribution of Boreal-Temperate species on Mediterranean mountains (Mayol et al. 2015, Iszkulo et al. 2016) and determine the presence of plant refugia, climatically stable areas that constitute key areas for the long-term persistence of species and genetic diversity, especially at present and future decades given the threat posed by the extensive environmental change processes operating in the Mediterranean region. These refugia, including large Mediterranean islands, represent ‘phylogeographical hotspots’; that is, significant reservoirs of unique genetic diversity favourable to the evolutionary processes of Mediterranean plants (Médail and Diadema 2009).

The island of Sardinia, the second largest in the whole Mediterranean basin, was already known to have a prevalent Mediterranean bioclimate, with a temperate bioclimate in the two main massifs of the island, the Gennargentu (centre-eastern Sardinian, maximum elevation 1834 m a.s.l.) and the Limbara (north-eastern Sardinia, maximum elevation 1359 m a.s.l.) (Arrigoni 1968). Recent detailed bioclimate analysis (Canu et al. 2015) also showed that the only mountain chain of the island named Marghine-Goceano (located between the Limbara and the Gennargentu massifs, maximum elevation at Mt. Rasu 1259 m a.s.l.) is characterised by a temperate bioclimate (in the sub-Mediterranean variant) along the ranges summit. Although the mountain floras of the Gennargentu and Limbara are well documented (Veri and Bruno 1974, Arrigoni and Camarda 2015), floristic information about the Marghine-Goceano range is lacking (Valsecchi and Corrias 1966).

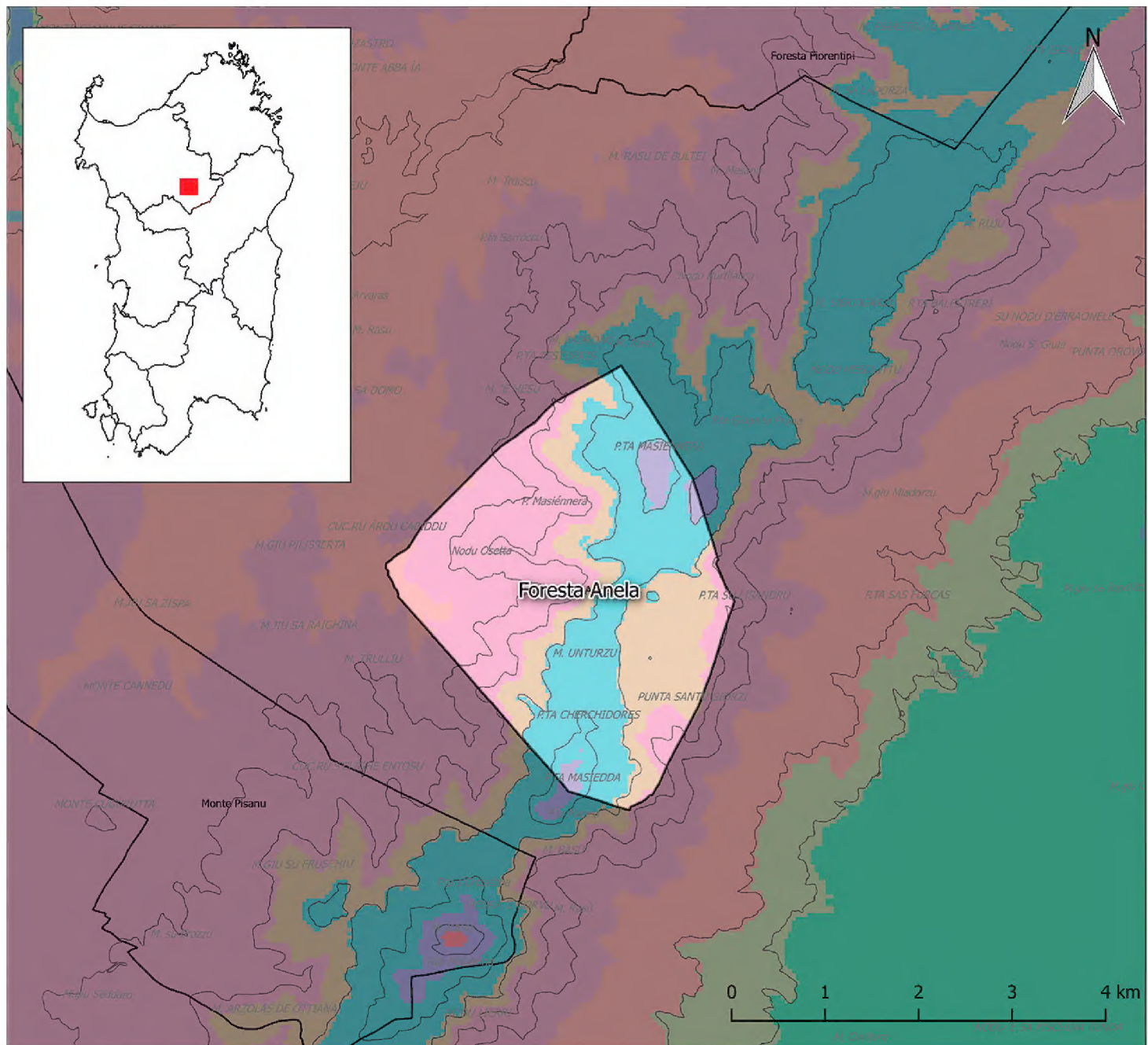
This paper goes some way to fill this knowledge gap by reporting on the indigenous flora of a forest domain located in the middle of the Marghine-Goceano range. Our aim was to provide a checklist of the flora located in this area to enable future characterisation of the biotic environment of this mountain area of Sardinia. This data will also allow the identification of target species to monitor and understand climate changes in the particular context of Mediterranean islands.

## Methods

### Study area

The forest domain of Anela is a public property since 1886, at present managed by the Sardinian regional agency Forestas (Fig. 1). The domain covers 1280 hectares of which 1200 ha fall in the municipality of Anela, 55 ha in that of Bultei (to the east) and 25 ha in that of Bono (to the west). The lowest altitude is about 600 m a.s.l. in locality *Badu Edras* whereas the summit point is at *Punta Masiedda* 1158 m a.s.l. The





**Figure 1.** The study area, Forest of Anela and its location in Sardinia (red rectangle on the inset map). Colours on the map represent different isobioclimates (derived from Canu et al. 2015). In the domain, we can recognise five different isobioclimates: Violet: upper mesotemperate (subMediterranean), lower humid, weak semi-continental; blue: lower supraMediterranean, lower humid, weak semi-continental; orange: upper mesoMediterranean, lower humid, weak semi-continental; lilac: upper mesoMediterranean, upper sub-humid, weak semi-continental; pink: upper mesoMediterranean, lower subhumid, weak semi-continental. Thick black lines represent domain limits; thin black lines represent altitude intervals of 100 m.

geographic coordinates of the forestry station headquarter are 40°27'14"N; 9°01'36"E. At present, the vegetation cover is mainly characterised by coppices and mature shrubs linked to sub-Mediterranean woods *Glechomo sardoae-Quercetum congestae* and *Sanicula europaeae-Quercetum ilicis* above 800 m a.s.l. and meso-Mediterranean *Loncomelo pyrenaici-Quercetum ichnusae* and *Galio scabri-Quercetum ilicis* below 800 m a.s.l., as described by Bacchetta et al. (2009). The 2004 forest census determined that 46% of this area was occupied by holm oak (*Quercus ilex* L.) woods, 2.7% by deciduous oak (*Q. pubescens* Willd.) woods, 23.4% by mixed woods of holm oak and deciduous oak, 0.8% by cork oak (*Q. suber* L.) woods, 2.8% by plantations with alien trees (*Abies*,



*Cedrus*, *Acer*, *Fagus*, *Pinus*), 14.7% by shrub communities (with *Erica arborea*, *Crataegus monogyna*, *Rubus ulmifolius*), 6.2% by dwarf communities (with *Helichrysum microphyllum* subsp. *tyrrhenicum*, *Thymus herba-barona*, *Genista desoleana*), 0.3% by rocky places and the rest by human activities (including buildings, an artificial lake and firebreaks) (Sechi and Falchi 2013). It should be noted that a large fire destroyed 800 hectares of the domain on 31 July 1945, so the wooded area decreased from 72.4% in 1910 to less than 20% in the 50s (Sechi and Falchi 2013).

In the ambit of the Sardinian-Corsican biogeographic province (as defined by Bacchetta et al. 2012), the study area falls in the Goceano-Logudorese sector (Fenu et al. 2014).

The geology of the study area comprises Palaeozoic granites and schists (Madrau 2013). The impermeable nature of these substrates has created a substantial aquifer evident by the presence of 39 springs (half perennial and half seasonal) in the study area (Farris 2013b).

Bioclimate analysis of 1971–2000 data (Canu et al. 2015) showed that 96.9% of the area falls in the Mediterranean Pluviseasonal Oceanic bioclimate, whereas 3.1% in the Temperate Oceanic bioclimate (submediterranean variant). A total of 64.6% of the area is included in the meso-Mediterranean thermotype, 32.3% in the supra-Mediterranean and 3.1% in the meso-Temperate.

Thermo-pluviometric data of the period 1951–1985 showed annual mean temperature of 11.2 °C and annual mean rainfall of 1040 mm; after the year 2000 temperatures did not vary significantly, whereas a reduction of ca. 30% in the annual rainfall was recorded. Late spring and summer rainfall (May–August) decreased even more (more than 50%, see Farris 2013a).

The study area is entirely included in the Natura 2000 site of community importance ITB 011102 “Catena del Marghine e Goceano”, extended on 14,984 ha and is also nominated as a Protection Oasis for wildlife “Foresta Anela”, managed by the Province of Sassari.

## Floristic research

Floristic research started in the year 2000 and was intensified in the years 2012–17 with regular monthly sampling. Each month, we made one day excursions, which covered three altitudinal ranges (< 800 m a.s.l.; 800–1000 m a.s.l.; > 1000 m a.s.l. on the third). For each excursion, we tried to visit as many habitats as possible in order to capture the highest environmental heterogeneity. Collected plants were stored at the Herbarium SS, where we also searched for specimens collected in previous decades (if present, they are reported in the floristic list).

Plant names were derived from the Euro+Med PlantBase (Euro+Med 2006–2018), except for: a) families not already included in this database for which we referred to the Checklists of Italian Flora (Conti et al. 2005; Bartolucci et al. 2018), APG IV (APG 2016); b) the family Orchidaceae (for which we follow GIROS (2016)); c) the genus *Orobanche*, for which we follow Domina and Arrigoni (2007); d) the genus *Dianthus*,



for which Bacchetta et al. (2010) is followed; e) and the species *Struthiopteris spicant* which we use in preference to *Blechnum spicant* (Gasper et al. 2016); f) for endemics, we also consulted Arrigoni et al. (1976–1991) and Peruzzi et al. (2014). The Italian floras (Pignatti 1982, 2017–2018) and the Sardinian flora (Arrigoni 2006–2015) were also consulted. When other relevant literature was followed, it is specified in the text.

Plant authorities and names were further verified using ‘The Plant List’, ‘The World Checklist of Selected Plant Families’ and ‘The International Plant Names Index’ (IPNI). Herbarium acronyms follow Thiers (2018).

The taxonomic circumscription of orders and families, as well as their sequence in the list was derived from Smith et al. (2006) for Pteridophytes; and APG III (APG 2009), APG IV (APG 2016) and Haston et al. (2009) for Angiosperms. Within each family, genera, species and subspecies are listed in alphabetical order. Species and subspecies are numbered progressively.

For each taxon we report:

Progressive number      Scientific name (with authority)      Biological type, Chorologic type  
Abundance (locality(ies) of collection is(are) specified only for uncommon or range restricted taxa): Habitat  
Notes (eventual)

Biological types are in accordance to Raunkiær (1934) and were verified on the collected samples and also in Pignatti (1982, 2017–2018); chorologic types were determined following maps reported in the Euro+Med PlantBase (Euro+Med 2006–2018) and again verified in Pignatti (1982, 2017–2018) and the other bibliographic sources reported in the text.

Geographical abbreviations are:

Atl.	Atlantic;	Medit.	Mediterranean;
Cauc.	Caucasian;	Medit. Mont.	Mediterranean montane;
Circumbor.	circum-boreal;	S. Europ. Orof.	Southern European Oro-
Cosmop.	cosmopolitan;		phylous;
Endem.	endemic;	Paleotemp.	paleo-temperate;
Euras.	Eurasian;	Paleotrop.	paleo-Tropical;
Eurimedit.	eur-Mediterranean;	Sib.	Siberian;
Europ.	European;	Stenomedit.	Steno-Mediterranean;
Eurosib.	Euro-Siberian;	Subatl.	sub-Atlantic;
It	Italy;	Subcosmop.	sub-cosmopolitan;
Itc	central Italy;	Submedit.	sub-Mediterranean;
Its	northern Italy;	Subtrop.	sub-Tropical;
Macaron.	Macaronesian;	Turan.	Turanian.

Here we consider as endemics *sensu stricto* all taxa limited to the Corsican-Sardinian biogeographic province (*sensu* Bacchetta et al. 2012), therefore including the Tuscan Archipelago. Other taxa are considered endemic *sensu lato*, which includes those present in western Mediterranean islands and continental areas – Calabria in Europe, Kabylies in Africa – as far as the Miocene part of the Hercynian chain (Hercynian endemics *sensu* Mansion et al. 2008). Finally, other endemics *sensu lato* are ‘administrative endemics’, i.e. taxa confined within Italian national borders (Peruzzi et al. 2014). For endemics, geographic abbreviations are as follows:

Ag	Algeria;	Hy	Hyères islands;
AT	Tuscan Archipelago;	Sa	Sardinia;
Bl	Balearic Islands;	Si	Sicily.
Co	Corsica;		

Abundance is expressed on the basis of the following criteria:

RR	range restricted: taxa present in only one locality within the study area or covering a surface not exceeding 1 hectare, i.e. <i>Mentha requienii</i> subsp. <i>requienii</i> ;
U	uncommon: taxa found in 2–5 localities within the study area, or covering a surface not exceeding 1 km <sup>2</sup> , i.e. <i>Arisarum vulgare</i> ;
L	localised: taxa present in 6 or more localities within the study area, but covering less than 2.5 km <sup>2</sup> , i.e. <i>Agrostis capillaris</i> ;
C	common: taxa covering more than 2.5 km <sup>2</sup> , i.e. <i>Quercus ilex</i> .

## Results

### Floristic list

#### Lycopodiopsida

### Isoetales

#### Isoetaceae

- |   |  |                          |
|---|--|--------------------------|
| 1 | <i>Isoetes histrix</i> Bory                                | G bulb, Stenomedit.-Atl. |
|   | U (Zuanne Cane Malu, near Mt. Masiennera): Temporary ponds |                          |

### Selaginellales

#### Selaginellaceae

- |   |  |                      |
|---|--|----------------------|
| 2 | <i>Selaginella denticulata</i> (L.) Spring | Ch rept, Stenomedit. |
|   | C: Woods, wet cliffs                       |                      |



## Polypodiopsida

### Osmundales

#### Osmundaceae

- 3      *Osmunda regalis* L.      G rhiz, Subcosmop.  
L: *Alnus glutinosa* woods, streams

### Polypodiales

#### Dennstaedtiaceae

- 4      *Pteridium aquilinum* (L.) Kuhn subsp. *aquilinum*    G rhiz, Cosmop.  
C: Woods, meadows, fringes, garrigues, shrublands

#### Pteridaceae

- 5      *Anogramma leptophylla* (L.) Link    T caesp, Cosmop.  
L: Shady rocks and cliffs

#### Aspleniaceae

- 6      *Asplenium adiantum-nigrum* L.      H ros, Paleotemp.  
C: Shady rocks and cliffs, sometimes woods  
Notes: since the taxon has been excluded from the Sardinian flora by Marchetti (2004), Arrigoni (2006–2015) and Bartolucci et al. (2018), here we consider it as new for the Sardinian flora.
- 7      *Asplenium onopteris* L.      H ros, Subtrop.  
C: Woods, sometimes cliffs
- 8      *Asplenium ceterach* L. subsp. *ceterach*      H ros, Euras.  
L: Walls
- 9      *Asplenium foreziense* Magnier      H ros, NW-Medit.-Mont.  
U (Badu Edras): Shady rocks and cliffs  
Notes: the taxon has been excluded from the Sardinian flora by Marchetti (2004) and Bartolucci et al. (2018), but confirmed by Arrigoni (2006–2015).
- 10      *Asplenium obovatum* Viv. subsp. *obovatum*    H ros, Stenomedit.  
U (Mt. Masiennera): Crevices at the top of the mountain
- 11      *Asplenium trichomanes* subsp. *quadrivalens* D.E. Mey.      H ros, Cosmop.  
C: Shady rocks and cliffs

#### Woodsiaceae

- 12      *Athyrium filix-femina* (L.) Roth      H Ros, Subcosmop.  
L: Wet places, mainly *Alnus glutinosa* woods

#### Blechnaceae

- 13      *Struthiopteris spicant* (L.) F.W.Weiss      H ros, Circumbor.  
RR (Few individuals in a wet wood near Sos Sauceddos spring): *Alnus glutinosa* wood



## Dryopteridaceae

- 14 *Polystichum setiferum* (Forssk.) Woynt. G rhiz, Circumbor.  
C: Woods

## Polypodiaceae

- 15 *Polypodium cambricum* L. subsp. *cambricum* H ros, Eurimedit.  
C: Rocks, big trees
- 16 *Polypodium interjectum* Shivas H ros, Paleotrop.  
U (Bidighinzos): Shady rocks

## Magnoliopsida

## Alismatales

## Araceae

- 17 *Arisarum vulgare* O. Targ. Tozz. G rhiz, Stenomedit.  
U (Bonu Trau, Badde Cherchi, Badu Edras): Woods and shrubland (lower altitudes)
- 18 *Arum italicum* Mill. subsp. *italicum* G rhiz, Stenomedit.  
L: Fringes
- 19 *Arum pictum* L. f. G rhiz, Endem. Sa-Co-AT-BI  
RR (Su Pizzu Sa Pedra): at the base of a cliff  
Notes: this taxon is not considered as an Italian endemic by Peruzzi et al. (2014)
- 20 *Lemna gibba* L. I nat, Subcosmop.  
L: Wet places, standing water
- 21 *Lemna minor* L. I nat, Subcosmop.  
RR (Su Francallossu spring): standing water

## Dioscoreales

## Dioscoreaceae

- 22 *Dioscorea communis* (L.) Caddick & Wilkin G rad, Eurimedit.  
C: Woods

## Liliales

## Colchicaceae

- 23 *Colchicum nanum* K. Perss. G bulb, Endem. Sa-Co  
L: Wet pastures and meadows

## Smilacaceae

- 24 *Smilax aspera* L. NP, Subtrop.  
C: Woods



## Liliaceae

- 25 *Gagea bohemica* (Zauschn.) Schult. & Schult.f. G bulb, Eurimedit.  
C: Pastures

## Asparagales

## Orchidaceae

- 26 *Anacamptis laxiflora* (Lam.) R. M. Bateman, Pridgeon & M. W. Chase  
G bulb, Eurimedit.  
L: Wet meadows  
Specimen examined (syn. *Orchis laxiflora* Lam.): Funtana Arile, Anela, 08 June 1980, B. Corrias, S. Diana (SS)
- 27 *Anacamptis longicornu* (Poir.) R. M. Bateman, Pridgeon & M. W. Chase  
G bulb, W-Stenomedit.  
Not found in the field during this research  
Specimen examined (syn. *Orchis longicornu* Poir.): S'Isfundadu, Anela, 13 May 1965, B. Corrias (SS)
- 28 *Anacamptis papilionacea* (L.) R. M. Bateman, Pridgeon & M. W. Chase  
G bulb, Eurimedit.  
C: Dry grasslands  
Specimen examined (syn. *Orchis papilionacea* L.): Funtana Arile, Anela, 08 June 1980, B. Corrias, S. Diana (SS)
- 29 *Dactylorhiza insularis* (Sommier) Landwehr G bulb, W-Stenomedit.  
Not found in the field during this research  
Specimen examined (syn. *D. sambucina* (L.) Soó): S'Isfundadu, Anela, 13 May 1965, B. Corrias (SS)
- 30 *Limodorum abortivum* (L.) Sw. G rhiz, Eurimedit.  
U (Littu Majore and Minda 'e Bassu - Minda 'e Supra): *Quercus ilex* woods
- 31 *Orchis provincialis* Balb. ex Lam. & DC. G bulb, Stenomedit.  
L: Clearings, fringes  
Specimens examined: S'Isfundadu, Anela, 13 May 1965, B. Corrias (2 specimens, SS)
- 32 *Serapias lingua* L. G bulb, Stenomedit.  
L: Wet meadows  
Specimen examined: Funtana Arile, Anela, 08 June 1980, B. Corrias, S. Diana (SS)
- 33 *Spiranthes spiralis* (L.) Chevall. G rhiz, Europ.-Cauc.  
U (Funtana Arile): Wet meadows

## Iridaceae

- 34 *Crocus minimus* DC. G bulb, Endem. Sa-Co  
C: Pastures
- 35 *Iris pseudacorus* L. G rhiz, Euras.  
U (Su Pranu): Flooded meadows, ponds



- 36 *Romulea columnae* Sebast. & Mauri subsp. *columnae* G bulb, Stenomedit.  
C: Pastures
- 37 *Romulea requienii* Parl. G bulb, Endem. Sa-Co  
C: Pastures

## Asphodelaceae

- 38 *Asphodelus ramosus* L. subsp. *ramosus* G rhiz, Stenomedit.  
C: Perennial grasslands, pastures, garrigues

## Amaryllidaceae

- 39 *Allium chamaemoly* L. subsp. *chamaemoly* G bulb, W-Stenomedit.  
L: Annual grasslands (lower altitudes)
- 40 *Allium guttatum* subsp. *sardoum* (Moris) Stearn G bulb, Stenomedit.  
C: Pastures, meadows
- 41 *Allium parviflorum* Viv. G bulb, Endem. Sa-Co  
L: Garrigues, rocky habitats
- 42 *Allium subhirsutum* L. G bulb, W-Stenomedit.  
C: Perennial grasslands
- 43 *Allium triquetrum* L. G bulb, W-Stenomedit.  
C: Fringes, woods
- 44 *Allium vineale* L. G bulb, Eurimedit.  
L: Perennial grasslands
- 45 *Leucojum aestivum* subsp. *pulchellum* (Salisb.) Briq. G bulb, Endem.  
Sa-Co-Bl  
L: Wet meadows  
Notes: This taxon is reported also in the Var (Southern France) (see: Tison and de Foucault 2014, Arrigoni 2006–2015; Pignatti 2017–2018) whereas the Euro+Med Plantbase considers it exclusive only in Sardinia, Corsica and the Balearic Islands.
- 46 *Pancratium illyricum* L. G bulb, Endem. Sa-Co-AT  
L: Garrigues

## Asparagaceae

- 47 *Asparagus acutifolius* L. G rhiz, Stenomedit.  
L: Woods and shrubland (lower altitudes)
- 48 *Drimia pancration* (Steinh.) J. C. Manning & Goldblatt G bulb, W-Stenomedit.  
L: Grasslands
- 49 *Leopoldia comosa* (L.) Parl. G bulb, Eurimedit.  
C: Grasslands, pastures
- 50 *Ornithogalum corsicum* Jord. & Fourr. G bulb, Endem. Sa-Co  
C: Pastures



- 51 *Ornithogalum pyrenaicum* L. G bulb, Eurimedit.  
C: Deciduous woods
- 52 *Prospero autumnale* (L.) Speta G bulb, Eurimedit.  
C: Grasslands, pastures
- 53 *Ruscus aculeatus* L. G rhiz, Eurimedit.  
C: Woods

## Poales

### Typhaceae

- 54 *Typha angustifolia* L. G rhiz, Circumbor.  
L: Artificial lake, flooded areas, streams

### Juncaceae

- 55 *Juncus articulatus* L. G rhiz, Circumbor.  
C: Wet meadows, temporary ponds
- 56 *Juncus bufonius* L. T caesp, Cosmop.  
C: Temporary ponds, wet soils
- 57 *Juncus capitatus* Weigel T scap, Medit.-Atl.  
C: Temporary ponds
- 58 *Juncus effusus* L. subsp. *effusus* H caesp, Cosmop.  
C: Wet meadows, temporary ponds
- 59 *Juncus hybridus* Brot. T caesp, Medit.-Atl.  
C: Temporary ponds
- 60 *Luzula forsteri* (Sm.) DC. H caesp, Eurimedit.  
C: Woods

### Cyperaceae

- 61 *Carex caryophyllea* Latourr. H scap, Euras.  
C: Wet pastures and meadows
- 62 *Carex distachya* Desf. H caesp, Stenomedit.  
C: Woods
- 63 *Carex divisa* Huds. G rhiz, Medit.-Atl.  
C: Wet meadows and pastures, temporary ponds, ditches
- 64 *Carex divulsa* Stokes H caesp, Eurimedit.  
C: Fringes
- 65 *Carex microcarpa* Moris He, Endem. Sa-Co-AT-Itc  
L: *Alnus glutinosa* woods, riparian vegetation
- 66 *Carex remota* L. H caesp, Europ.-Cauc.  
U (Badu Addes): *Alnus glutinosa* wood
- 67 *Cyperus longus* L. G rhiz, Paleotemp.  
C: Wet meadows, riparian vegetation
- Notes: some authors exclude the presence of this species from Sardinia (Desfayes 2004, Arrigoni 2006–2015, Bartolucci et al. 2018) and consider the pres-



ence of *Cyperus badius* Desf. instead. In the Euro+Med Plantbase, *C. badius* is considered a heterotypic synonym of *C. longus*.

- 68 *Eleocharis palustris* (L.) Roem. & Schult. subsp. *palustris* G rhiz, Subcosmop.  
L: Wet meadows

Gramineae (*nom. altr.* Poaceae)

- 69 *Aegilops geniculata* Roth T scap, Stenomedit.-Turan.  
L: Annual grasslands
- 70 *Agrostis capillaris* L. H caesp, Circumbor.  
L: Wet pastures and meadows  
Notes: this taxon is new for the Sardinian flora following Pignatti (1982), Conti et al. (2005), Arrigoni (2006–2015), Pignatti (2017–2018), Bartolucci et al. (2018) and the Euro+Med PlantBase.
- 71 *Aira caryophylla* L. subsp. *caryophylla* T scap, Subtrop.  
C: Annual grasslands
- 72 *Alopecurus bulbosus* Gouan subsp. *bulbosus* H caesp, Eurimedit.-Subatl.  
L: Wet pastures and meadows
- 73 *Anisantha diandra* (Roth) Tutin T scap, Eurimedit.  
C: Annual grasslands
- 74 *Anisantha madritensis* (L.) Nevski subsp. *madritensis* T scap, Eurimedit.  
C: Annual grasslands, pastures
- 75 *Anthoxanthum odoratum* L. H caesp, Euras.  
C: Wet pastures and meadows
- 76 *Arrhenatherum elatius* subsp. *sardoum* (Em. Schmid) Gamisans H caesp, W-Stenomedit.  
L: Garrigues, rocky habitats (higher altitudes)
- 77 *Avena barbata* Link subsp. *barbata* T scap, Eurimedit.  
C: Annual grasslands
- 78 *Brachypodium retusum* (Pers.) P. Beauv. H caesp, W-Stenomedit.  
C: Perennial grasslands on rocky or stony soils
- 79 *Brachypodium sylvaticum* (Huds.) P. Beauv. subsp. *sylvaticum* H caesp, Paleotemp.  
C: Woods, fringes
- 80 *Briza maxima* L. T scap, Subtrop.  
C: Annual grasslands, pastures
- 81 *Briza minor* L. T scap, Subcosmop.  
U (near Mt. Masiennera): Wet pastures and meadows
- 82 *Bromus hordeaceus* L. subsp. *hordeaceus* T scap, Subcosmop.  
C: Annual grasslands, pastures
- 83 *Bromus scoparius* L. T scap, Stenomedit.  
U (Top of Mt. Masiennera): Annual grasslands
- 84 *Catabrosa aquatica* (L.) P. Beauv. G rhiz, Circumbor.  
L: Wet soils



- 85 *Cynodon dactylon* (L.) Pers. G rhiz, Cosmop.  
C: Wet pastures and meadows
- 86 *Cynosurus cristatus* L. H caesp, Europ.-Cauc.  
C: Wet pastures and meadows
- 87 *Cynosurus echinatus* L. T scap, Eurimedit.  
C: Annual grasslands, fringes
- 88 *Cynosurus effusus* Link T scap, Stenomedit.  
C: Annual grasslands, fringes
- 89 *Dactylis glomerata* subsp. *hispanica* (Roth) Nyman H caesp, Stenomedit.  
C: Perennial grasslands
- 90 *Danthonia decumbens* (L.) DC. subsp. *decumbens* H caesp, Europ.  
L: Wet pastures and meadows
- 91 *Dasypyrum villosum* (L.) P. Candargy T Scap, Eurimedit.-Turan.  
L: Annual grasslands
- 92 *Festuca morisiana* Parl. subsp. *morisiana* H caesp, Endem. Sa  
L: Wet meadows and pastures
- 93 *Glyceria notata* Chevall. G rhiz, Subcosmop.  
L: Wet habitats
- 94 *Holcus lanatus* L. subsp. *lanatus* H caesp, Circumbor.  
C: Wet meadows
- 95 *Hordeum geniculatum* All. T scap, Stenomedit.  
C: Wet meadows and pastures, temporary ponds
- 96 *Lagurus ovatus* L. subsp. *ovatus* T scap, Eurimedit.  
C: Annual grasslands, pastures
- 97 *Lolium perenne* L. subsp. *perenne* H caesp, Euras.  
C: Wet pastures
- 98 *Lolium rigidum* Gaudin subsp. *rigidum* T scap, Subtrop.  
C: Pastures on arid soil
- 99 *Melica ciliata* L. subsp. *ciliata* H caesp, Eurimedit.  
U (Mt. Masiennera): Rocky habitats
- 100 *Melica minuta* L. H caesp, Stenomedit.  
C: Fringes
- 101 *Melica uniflora* Retz. H caesp, Paleotemp.  
L: Deciduous woods, fringes
- 102 *Neoschischkinia pourrettii* (Willd.) Valdés & H. Scholz T scap, W-Stenomedit.  
L: Temporary ponds
- 103 *Piptatherum miliaceum* (L.) Coss. subsp. *miliaceum* H caesp, Stenomedit.  
L: Road edges (lower altitudes)
- 104 *Poa annua* L. subsp. *annua* T caesp, Cosmop.  
C: Annual grasslands, pastures
- 105 *Poa balbisii* Parl. H caesp, Endem. Sa-Co  
U (Mt. Masiennera): Garrigues, rocky habitats

- 106 *Poa bulbosa* L. subsp. *bulbosa* H caesp, Paleotemp.  
C: Pastures
- 107 *Poa infirma* Kunth T caesp, Eurimedit.  
C: Mud, wet soils
- 108 *Poa nemoralis* L. subsp. *nemoralis* H caesp, Circumbor.  
C: Woods
- 109 *Poa trivialis* L. subsp. *trivialis* H caesp, Euras.  
C: Wet meadows
- 110 *Vulpia ligustica* (All.) Link T caesp, Stenomedit.  
C: Pastures
- 111 *Vulpia myuros* (L.) C. C. Gmel. subsp. *myuros* T caesp, Subcosmop.  
C: Pastures
- 112 *Vulpia sicula* (C. Presl) Link H caesp, W-Medit.-Mont.  
C: Pastures, grasslands

## Ranunculales

### Papaveraceae

- 113 *Fumaria bastardii* Boreau T scap, Subatl.  
C: Annual grasslands, fringes
- 114 *Fumaria officinalis* L. subsp. *officinalis* T scap, Paleotemp.  
C: Annual grasslands, fringes
- 115 *Papaver rhoeas* L. subsp. *rhoeas* T scap, E-Medit.  
C: Pastures, grasslands

### Ranunculaceae

- 116 *Anemone hortensis* L. subsp. *hortensis* G bulb, N-Medit.  
RR (Su Tattharesu): Perennial grasslands
- 117 *Clematis vitalba* L. P lian, Europ.-Cauc.  
C: Woods, mantles
- 118 *Ficaria verna* Huds. subsp. *verna*. G bulb, Euras.  
C: Woods
- 119 *Ranunculus bulbosus* subsp. *aleae* (Willk.) Rouy & Foucaud H scap, Euras.  
C: Grasslands, fringes, woods
- 120 *Ranunculus bullatus* L. subsp. *bullatus* H ros, Stenomedit.  
C: Annual grasslands
- 121 *Ranunculus cordiger* Viv. subsp. *cordiger* H scap, Endem. Sa-Co  
L: Wet meadows, temporary ponds
- 122 *Ranunculus macrophyllus* Desf. H scap, SW-Medit.  
L: Wet meadows
- 123 *Ranunculus muricatus* L. T scap, Eurimedit.  
C: Mud, wet meadows
- 124 *Ranunculus ophioglossifolius* Vill. T scap, Eurimedit.  
L: Mud, temporary ponds



- 125 *Ranunculus paludosus* Poir. subsp. *paludosus* H scap, Stenomedit.  
C: Pastures
- 126 *Ranunculus sardous* Crantz T scap, Eurimedit.  
C: Mud, temporary ponds

## Saxifragales

### Paeoniaceae

- 127 *Paeonia corsica* Tausch G rhiz, Endem. Sa-Co  
L: Woods, clearings

### Saxifragaceae

- 128 *Saxifraga tridactylites* L. T scap, Eurimedit.  
L: Annual grasslands

### Crassulaceae

- 129 *Sedum caeruleum* L. T scap, SW-Medit.  
C: Rocky habitats, annual grasslands
- 130 *Sedum cepaea* L. T scap, Submedit.-Subatl.  
C: Rocky habitats, annual grasslands
- 131 *Sedum rubens* L. T scap, Eurimedit.-Subatl.  
C: Rocky habitats, annual grasslands
- 132 *Sedum stellatum* L. T scap, Stenomedit.  
C: Rocky habitats, annual grasslands
- 133 *Sedum villosum* subsp. *glandulosum* (Moris) P. Fourn. H scap, Endem.  
Sa-Ag  
C: Rocky habitats, annual grasslands
- 134 *Umbilicus rupestris* (Salisb.) Dandy subsp. *rupestris* G bulb, Medit.-Atl.  
C: Rocky habitats

## Fabales

### Leguminosae (nom. altr. Fabaceae)

- 135 *Cytisus villosus* Pourr. P caesp, W-Stenomedit.  
C: Shrubland, mantles
- 136 *Dorycnium rectum* (L.) Ser. H scap, Stenomedit.  
L: Wet habitats
- 137 *Genista corsica* (Loisel.) DC. NP, Endem. Sa-Co  
L: Garrigues on rocky soils
- 138 *Genista desoleana* Vals. NP, Endem. Sa-Co-Its  
C: Garrigues, dwarf shrubs  
Specimens examined: Punta Chelchidores, Anela, 18 July 1972, F. Valsecchi (3 specimens, SS)
- 139 *Lathyrus aphaca* L. T scap, Eurimedit.  
C: Pastures, fringes

- 140 *Lathyrus sphaericus* Retz. T Scap, Eurimedit.  
L: Pastures
- 141 *Lotus alpinus* (DC.) Ramond H scap, Orof. S-Europ.  
C: Wet pastures and meadows
- 142 *Lotus angustissimus* L. T scap, Eurimedit.  
L: Temporary ponds
- 143 *Lotus conimbricensis* Brot. T scap, W- Stenomedit.  
C: Annual grasslands
- 144 *Lotus hispidus* DC. T scap, W-Medit.  
C: Annual grasslands
- 145 *Lupinus angustifolius* L. subsp. *angustifolius* T scap, Stenomedit.  
C: Annual grasslands
- 146 *Medicago polymorpha* L. T scap, Eurimedit.  
C: Pastures, annual grasslands
- 147 *Ononis spinosa* L. subsp. *spinosa* Ch suffr, Eurimedit.  
C: Grasslands, pastures
- 148 *Ornithopus compressus* L. T scap, Eurimedit.  
C: Annual grasslands
- 149 *Ornithopus pinnatus* (Mill.) Druce T Scap, Medit.-Atl.  
L: Pastures
- 150 *Trifolium angustifolium* L. T scap, Eurimedit.  
C: Annual grasslands
- 151 *Trifolium arvense* L. T scap, Paleotemp.  
C: Pastures
- 152 *Trifolium campestre* Schreb. T scap, Paleotemp.  
C: Annual grasslands
- 153 *Trifolium glomeratum* L. T Scap, Eurimedit.  
L: Pastures
- 154 *Trifolium incarnatum* subsp. *molinerii* (Hornem.) Syme T scap, Eurimedit.  
C: Grasslands, pastures
- 155 *Trifolium micranthum* Viv. T scap, Paleotemp.  
C: Annual grasslands
- 156 *Trifolium nigrescens* Viv. subsp. *nigrescens* T scap, N-Medit.  
C: Pastures
- 157 *Trifolium pratense* L. H scap, Eurosib.  
C: Wet meadows and pastures
- 158 *Trifolium repens* subsp. *prostratum* Nyman H rept, Eurimedit.  
C: Wet meadows and pastures
- 159 *Trifolium spumosum* L. T scap, Stenomedit.  
C: Annual grasslands
- 160 *Trifolium squarrosum* L. T scap, Eurimedit.  
L: Pastures
- 161 *Trifolium stellatum* L. T scap, Eurimedit.  
C: Annual grasslands, pastures



- 162 *Trifolium subterraneum* subsp. *yanninicum* Katzn. & F. H. W. Morley  
T rept, E-Medit.  
C: Pastures
- 163 *Trifolium tomentosum* L. T rept, Paleotemp.  
C: Annual grasslands, pastures
- 164 *Vicia cracca* L. subsp. *cracca* H scap, Euras.  
C: Fringes
- 165 *Vicia lathyroides* L. T scap, Eurimedit.  
C: Fringes
- 166 *Vicia lutea* L. subsp. *lutea* T scap, Eurimedit.  
C: Fringes
- 167 *Vicia villosa* subsp. *ambigua* (Guss.) Kergu len H Scap, W-Stenomedit.  
L: Fringes
- 168 *Vicia villosa* Roth subsp. *villosa* T scap, Eurimedit.  
C: Fringes

## Rosales

### Rosaceae

- 169 *Agrimonia eupatoria* L. subsp. *eupatoria* H scap, Subcosmop.  
C: Fringes
- 170 *Crataegus monogyna* Jacq. P caesp, Paleotemp.  
C: Shrublands, woods, mantles
- 171 *Fragaria vesca* L. subsp. *vesca* H rept, Eurosib.  
C: Deciduous woods, fringes
- 172 *Geum urbanum* L. H scap, Circumbor.  
C: Deciduous woods, fringes  
Specimen examined: Caserma Forestale Anela, sine die, Barba (SS)
- 173 *Malus pumila* Mill. P scap, CW-Euras.  
L: Woods, mantles  
Notes: in accordance with Bagella and Urbani (2006), this is the valid name for *Malus domestica* Borkh. (nom. illeg.), also reported in the Euro+Med Plant-Base. Yet Galasso et al. (2018) call a taxon *Malus domestica*, considering it as a non-native species, while Camarda and Valsecchi (2008), Arrigoni (2006–2015) and Pignatti (2017–2018) still call it *M. dasyphylla*. Finally, Bartolucci et al. (2018) report the taxon *M. sylvestris* in Sardinia. *Malus pumila* is reported as a synonym of *M. domestica* by Galasso et al. (2018), it is excluded from the Sardinian flora by Arrigoni (2006–2015), finally, it was not mentioned by Camarda and Valsecchi (2008). In the Euro+Med Plantbase, *Malus pumila* Mill. is the valid name for *Malus domestica* Borkh. The populations we have examined in the Marghine-Goceano range (not only the forest domain of Anela) have the characters of *Malus domestica*, not *M. sylvestris*.
- 174 *Potentilla reptans* L. H ros, Paleotemp.  
C: Wet meadows

- 175 *Prunus avium* (L.) L. P scap, Pontic  
L: Woods
- 176 *Prunus domestica* subsp. *insititia* (L.) Bonnier & Layens P scap  
U (Su Cantareddu): Mantles
- 177 *Prunus spinosa* L. subsp. *spinosa* P caesp, Europ.-Cauc.  
C: Shrublands
- 178 *Pyrus communis* subsp. *pyraster* (L.) Ehrh. P scap, Euras.  
L: Woods, mantles
- 179 *Pyrus spinosa* Forssk. P caesp, Stenomedit.  
C: Shrublands, mantles, woods
- 180 *Rosa canina* L. NP, Paleotemp.  
C: Shrublands
- 181 *Rosa sempervirens* L. NP, Stenomedit.  
L: Woods, shrublands (lower altitudes)
- 182 *Rosa subcanina* (Christ) Vuk. NP, Europ.  
C: Shrublands
- 183 *Rubus ulmifolius* Schott NP, Eurimedit.  
C: Shrublands, woods
- 184 *Sanguisorba minor* subsp. *balearica* (Bourg. ex Nyman) Muñoz Garm. & C.  
Navarro H scap, Eurimedit.  
C: Grasslands

## Ulmaceae

- 185 *Ulmus minor* Mill. subsp. *minor* P caesp, Europ.-Cauc.  
L: Woods

## Cannabaceae

- 186 *Celtis australis* L. subsp. *australis* P scap, Eurimedit.  
RR (Pedru Addes): Wood edge

## Moraceae

- 187 *Ficus carica* L. subsp. *carica* P scap, Medit.-Turan.  
U (Badu Edras): Riparian vegetation

## Urticaceae

- 188 *Parietaria lusitanica* L. subsp. *lusitanica* T rept, Stenomedit.  
C: Buildings, fringes
- 189 *Urtica atrovirens* Loisel. H scap, Endem. Sa-Co-Bl-AT-Itc  
L: Ruderal vegetation
- 190 *Urtica dioica* L. subsp. *dioica* H scap, Subcosmop.  
C: Ruderal vegetation



**Fagales**

## Fagaceae

- 191 *Quercus ilex* L. P scap, Stenomedit.

C: Woods

- 192 *Quercus pubescens* Willd. agg. P caesp, SE-Europ.

C: Woods

Notes: There are many controversial treatments for describing the variation within *Q. pubescens* (Mossa et al. 1998, 1999). Until the various treatments are resolved, we prefer to treat this variation as a complex (or aggregate) within *Q. pubescens* s.l.

- 193 *Quercus suber* L. P scap, W-Eurimedit.

L: Woods

## Betulaceae

- 194 *Alnus glutinosa* (L.) Gaertn. subsp. *glutinosa* P scap, Paleotemp.

L: Streams, wet places, springs

**Oxalidales**

## Oxalidaceae

- 195 *Oxalis corniculata* L. subsp. *corniculata* H rept, Eurimedit.

L: Walls, buildings

**Malpighiales**Guttiferae (*nom. altr.* Clusiaceae)

- 196 *Hypericum androsaemum* L. NP, W-Eurimedit.-Subatl.

L: Wet habitats, springs

- 197 *Hypericum hircinum* L. subsp. *hircinum* NP, Endem. Sa-Co-AT

L: Springs, streams, *Alnus glutinosa* woods

Notes: *H. hircinum* includes several subspecies, amongst which the subsp. *hircinum* is exclusive of Sardinia, Corsica and the Tuscan Archipelago (Carta and Peruzzi 2015)

- 198 *Hypericum perforatum* L. subsp. *perforatum* H scap, Paleotemp.

C: Fringes, road edges

## Violaceae

- 199 *Viola alba* subsp. *dehnhardtii* (Ten.) W. Becker H ros, Eurimedit.

C: Woods, fringes

- 200 *Viola reichenbachiana* Jord. ex Boreau H scap, Eurosib.

C: Deciduous woods

Notes: it was excluded for the Sardinian flora by Arrigoni (2006–2015), but later confirmed by Mereu (2012) for the Gennargentu massif

## Salicaceae

- 201 *Salix cinerea* subsp. *oleifolia* Macreight P caesp, W-Medit.-Atl.  
L: Streams, springs
- 202 *Salix purpurea* L. P scap, Euras.  
L: Ditches

## Euphorbiaceae

- 203 *Euphorbia characias* L. subsp. *characias* NP, Stenomedit.  
C: Woods, shrublands (lower altitudes)
- 204 *Euphorbia helioscopia* L. subsp. *helioscopia* T scap, Cosmop.  
C: Annual grasslands
- 205 *Euphorbia pithyusa* subsp. *cupanii* (Guss. ex Bertol.) Radcl.-Sm. G rhiz,  
Endem. Sa-Co-Si  
C: Perennial grasslands, pastures
- 206 *Euphorbia semiperfoliata* Viv. G rhiz, Endem. Sa-Co  
L: Woods, fringes

## Linaceae

- 207 *Linum bienne* Mill. H bienn, Eurimedit.  
C: Annual grasslands

**Geraniales**

## Geraniaceae

- 208 *Erodium chium* (L.) Willd. T scap, Eurimedit.  
L: Pastures
- 209 *Erodium ciconium* (L.) L'Hér. T scap, Eurimedit.-Pontic  
C: Pastures
- 210 *Erodium cicutarium* (L.) L'Hér. T scap, Subcosmop.  
C: Pastures
- 211 *Geranium purpureum* Vill. T scap, Eurimedit.  
C: Woods, fringes
- 212 *Geranium robertianum* L. T scap, Subcosmop.  
C: Woods, fringes
- 213 *Geranium rotundifolium* L. T scap, Paleotemp.  
C: Woods, fringes

**Myrtales**

## Lythraceae

- 214 *Lythrum portula* (L.) D. A. Webb T rept, S-Europ.-S-Sib.  
L: Temporary ponds

## Onagraceae

- 215 *Epilobium montanum* L. H scap, Euras.  
C: Woods



**Sapindales**

## Sapindaceae

- 216 *Acer monspessulanum* L. subsp. *monspessulanum* P caesp, Eurimedit.  
L: Woods and mantles

**Malvales**

## Malvaceae

- 217 *Althaea hirsuta* L. T scap, Eurimedit.  
L: Annual grasslands
- 218 *Malva olbia* (L.) Alef. P caesp, Stenomedit.  
C: Shrublands on wet soils
- 219 *Malva sylvestris* L. H scap, Eurosib.  
C: Grasslands, fringes

## Cistaceae

- 220 *Cistus monspeliensis* L. NP, Stenomedit.  
C: Garrigues (lower altitudes)
- 221 *Cistus salviifolius* L. NP, Stenomedit.  
C: Garrigues
- 222 *Tuberaria guttata* (L.) Fourr. T scap, Eurimedit.  
C: Annual grasslands

**Brassicales**

## Resedaceae

- 223 *Sesamoides purpurascens* subsp. *spathulata* (Moris) Lambinon & Kergu len  
H Scap, W-Medit.-Mont.  
C: Dirty tracks, trampled places

Cruciferae (*nom. altr.* Brassicaceae)

- 224 *Arabidopsis thaliana* (L.) Heynh. T scap, Paleotemp.  
C: Annual grasslands, pastures
- 225 *Capsella bursa pastoris* (L.) Medik. subsp. *bursa-pastoris* H bienn, Cos-  
mop.  
C: Annual grasslands, pastures
- 226 *Cardamine flexuosa* With. H scap, Circumbor.  
C: Fringes
- 227 *Cardamine hirsuta* L. T scap, Cosmop.  
C: Fringes
- 228 *Draba muralis* L. T scap, Circumbor.  
L: Cliffs, road edges
- 229 *Erophila verna* subsp. *praecox* (Steven) Walters T scap, Eurimedit.  
C: Annual grasslands
- 230 *Morisia monanthos* (Viv.) Asch. H ros, Endem. Sa-Co  
U (Near Mt. Masiennera): Wet meadows

- 231 *Nasturtium officinale* (L.) R. Br. H scap, Cosmop.  
L: Muds, streams
- 232 *Raphanus raphanistrum* L. subsp. *raphanistrum* T scap, Eurimedit.  
C: Grasslands
- 233 *Sisymbrium officinale* (L.) Scop. T scap, Paleotemp.  
C: Pastures
- 234 *Teesdalia coronopifolia* (J.P. Bergeret) Thell. T scap, Eurimedit.  
C: Pastures

## Santalales

### Santalaceae

- 235 *Osyris alba* L. NP, Eurimedit.  
L: Woods, clearings, rocky habitats

## Caryophyllales

### Plumbaginaceae

- 236 *Armeria sardoa* Spreng. subsp. *sardoa* Ch suffr, Endem. Sa  
L: Garrigues, rocky habitats

### Polygonaceae

- 237 *Rumex bucephalophorus* L. subsp. *bucephalophorus* T scap, Eurimedit.-Macaron.  
C: Annual grasslands
- 238 *Rumex crispus* L. H scap, Subcosmop.  
C: Wet meadows
- 239 *Rumex pulcher* L. subsp. *pulcher* H scap, Eurimedit.  
C: Wet meadows
- 240 *Rumex scutatus* subsp. *glaucescens* (Guss.) Brullo, Scelsi & Spamp. H scap, Endem. Sa-Si  
L: Rocky habitats
- 241 *Rumex thyrsoides* Desf. H scap, W-Medit.  
C: Fringes

### Caryophyllaceae

- 242 *Arenaria balearica* L. Ch suffr, Endem. Sa-Co-Bl-AT  
L: Shady rocks and cliffs  
Specimens examined: S'Isfundadu, Anela, 25 May 1966, B. Corrias (2 specimens, SS); S'Isfundadu, Anela, 18 June 1965, F. Valsecchi (1 specimen, SS).
- 243 *Cerastium gibraltarium* Boiss. Ch suffr, Orof. W-Medit.  
L: Garrigues  
Notes: in the Euro+Med Plantbase, *Cerastium boissierianum* Greuter et Burdet is considered a synonym of *C. gibraltarium*
- 244 *Cerastium glomeratum* Thuill. T scap, Eurimedit.  
C: Pastures



- 245 *Cerastium ligusticum* subsp. *palustre* (Moris) P. D. Sell et Whitehead T scap,  
Endem. Sa-Co  
RR (near Mt. Masiennera): Wet pastures and meadows
- 246 *Corrigiola telephiifolia* Pourr. H Ros, W-Medit.  
L: Trampled sites, dirty roads  
Specimen examined: Badu Addes, Anela, September 1962 (sine die), sine coll. (SS)
- 247 *Dianthus ichnusae* subsp. *toddei* Bacch., Brullo, Casti et Giusso H scap,  
Endem. Sa  
L: Garrigues, rocky habitats  
Notes: this taxon is exclusive for the Goceano mountain range (Bacchetta et al. 2010).
- 248 *Moenchia erecta* (L.) P. Gaertn., B. Mey. & Scherb. subsp. *erecta* T scap,  
Medit.-Atl.  
C: Pastures
- 249 *Petrorhagia dubia* (Raf.) G. López & Romo T scap, S-Medit.  
C: Pastures
- 250 *Petrorhagia saxifraga* (L.) Link H caesp, Eurimedit.  
C: Garrigues, rocky habitats
- 251 *Sagina apetala* Ard. T scap, Eurimedit.  
L: Annual grasslands, dirty tracks
- 252 *Sagina procumbens* L. H caesp, Subcosmop.  
L: Wet places, springs  
Specimen seen: Badu Addes, Anela, sine die, Barba (SS)
- 253 *Sagina subulata* (Sw.) C. Presl H caesp, Medit.-Atl.  
L: Wet meadows, rocky habitats (higher altitudes)  
Notes: for this taxon, recently the name *S. alexandrae* Iamónico has been proposed (Iamónico 2016)
- 254 *Silene gallica* L. T scap, Eurimedit.  
C: Pastures
- 255 *Silene laeta* (Aiton) Godr. T scap, W-Stenomedit.  
L: Muddy places, wet meadows, temporary ponds
- 256 *Silene latifolia* Poir. H bienn, Paleotemp.  
C: Fringes
- 257 *Silene vulgaris* (Moench) Garcke subsp. *vulgaris* H scap, Paleotemp.  
C: Fringes
- 258 *Spergula arvensis* L. T scap, Subcosmop.  
C: Pastures
- 259 *Stellaria media* (L.) Cirillo subsp. *media* T rept, Cosmop.  
C: Ruderal vegetation, woods, fringes

## Amaranthaceae

- 260 *Chenopodium album* L. subsp. *album* T Scap, Subcosmop.  
Not found in the field during this research

Specimens examined: Badu Addes, Anela, 09 September 1962, Barba (2 specimens, SS).

## Portulacaceae

- 261 *Montia fontana* subsp. *amporitana* Sennen T scap, Medit-Mont. Subatl.  
C: Mud, flooded soils

## Ericales

### Primulaceae

- 262 *Anagallis arvensis* L. T rept, Eurimedit.  
C: Annual grasslands
- 263 *Asterolinon linum-stellatum* (L.) Duby T Scap, Stenomedit.  
L: Annual grasslands, pastures
- 264 *Cyclamen repandum* Sibth. & Sm. subsp. *repandum* G bulb, NW-Stenomedit.  
C: Woods

### Ericaceae

- 265 *Arbutus unedo* L. P caesp, Stenomedit.  
RR (Littu Majore): Wood
- 266 *Erica arborea* L. P caesp, Stenomedit.  
C: Shrublands, woods

## Gentianales

### Rubiaceae

- 267 *Cruciata glabra* (L.) Ehrend. H scap, Euras.  
C: Grasslands, pastures  
Specimen examined: Badu Addes, Anela, 18 July 1972, B. Corrias, S. Diana, F. Valsecchi (SS).
- 268 *Galium aparine* L. subsp. *aparine* T scap, Euras.  
C: Fringes
- 269 *Galium corsicum* Spreng. H scap, Endem. Sa-Co  
L: Rocky habitats
- 270 *Galium debile* Desv. H scap, Eurimedit.  
L: Wet habitats
- 271 *Galium rotundifolium* L. H scap, Orof.-W-Euras.  
L: Woods (higher altitudes)
- 272 *Rubia peregrina* L. subsp. *peregrina* P lian, Stenomedit.-Macaron.  
C: Woods
- 273 *Sherardia arvensis* L. T scap, Eurimedit.  
C: Pastures, annual grasslands
- 274 *Theligonum cynocrambe* L. T scap, Stenomedit.  
C: Annual grasslands, fringes



## Gentianaceae

- 275 *Exaculum pusillum* (Lam.) Caruel T scap, W-Eurimedit.  
RR (Minda 'e Bassu): Temporary pond

**Boraginales**

## Boraginaceae

- 276 *Anchusa hybrida* Ten. H scap, Stenomedit.  
Not found in the field during this research  
Specimens examined: Badu Addes, Anela, 22 October 1963, F. Valsecchi, Barba (3 specimens, SS).
- 277 *Cynoglossum creticum* Mill. H bienn, Eurimedit.  
L: Fringes
- 278 *Echium plantagineum* L. T Scap, Eurimedit.  
C: Pastures, grasslands
- 279 *Myosotis arvensis* (L.) Hill subsp. *arvensis* T scap, Europ.-W-Asian  
C: Annual grasslands, pastures
- 280 *Myosotis sicula* Guss. T scap, N-Eurimedit.  
L: Wet meadows, temporary ponds

## Convolvulaceae

- 281 *Convolvulus althaeoides* L. H scand, Stenomedit.  
C: Perennial grasslands
- 282 *Convolvulus arvensis* L. G rhiz, Paleotemp.  
C: Perennial grasslands
- 283 *Cuscuta epithymum* subsp. *corsicana* (Yunck.) Lambinon T par, Endem.  
Sa-Co  
L: Garrigues (mainly parasite on *Genista desoleana*)

**Solanales**

## Solanaceae

- 284 *Solanum dulcamara* L. NP, Paleotemp.  
U (Su Pranu): Riparian vegetation

**Lamiales**

## Oleaceae

- 285 *Phillyrea latifolia* L. P caesp, Stenomedit.  
C: Woods, shrubland (lower altitude)

## Plantaginaceae

- 286 *Callitriche stagnalis* Scop. I rad, Euras.  
L: Temporary ponds, springs, muddy soils
- 287 *Cymbalaria aequitriloba* (Viv.) A. Chev. subsp. *aequitriloba* Ch rept, Endem.  
Sa-Co-Bl-AT  
L: Shady rocks and cliffs

- 288 *Digitalis purpurea* L. subsp. *purpurea* H scap, W-Eurimedit.  
C: Fringes, clearings
- 289 *Linaria arvensis* (L.) Desf. T scap, Submedit.-Subatl.  
C: Annual grasslands
- 290 *Linaria pelisseriana* (L.) Mill. T scap, Medit.-Atl.  
C: Pastures
- 291 *Plantago coronopus* L. T scap, Eurimedit.  
C: Grasslands, pastures
- 292 *Plantago lagopus* L. subsp. *lagopus* T scap, Stenomedit.  
C: Annual grasslands, pastures
- 293 *Plantago lanceolata* L. H ros, Euras.  
C: Grasslands
- 294 *Plantago major* L. subsp. *major* H ros, Euras.  
L: Wet meadows
- 295 *Plantago weldenii* Rchb. T scap, Stenomedit.  
C: Annual grasslands
- 296 *Veronica anagallis-aquatica* L. subsp. *anagallis-aquatica* H scap, Cosmop.  
L: Mud, springs, ditches  
Specimen examined: Punta Chelchidores est, Anela, 18 July 1972, B. Corrias, S. Diana, F. Valsecchi (SS)
- 297 *Veronica arvensis* L. T scap, Subcosmop.  
C: nitrophilous vegetation
- 298 *Veronica hederifolia* L. subsp. *hederifolia* T scap, Euras.  
C: Woods, fringes
- 299 *Veronica verna* subsp. *brevistyla* (Moris) Rouy T scap, Endem. Sa-Co  
L: Pastures (higher altitudes)

## Scrophulariaceae

- 300 *Scrophularia trifoliata* L. H caesp, Endem. Sa-Co-AT  
L: Rocky habitats  
Specimen examined: Badu Addes, Anela, 18 July 1972, F. Valsecchi (SS)
- 301 *Scrophularia umbrosa* Dumort. subsp. *umbrosa* H Scap, Euras.  
Not found in the field during this research  
Specimens examined: Badu Addes, Anela, 18 July 1973, F. Valsecchi (3 specimens, SS)
- 302 *Verbascum pulverulentum* Vill. H bienn, Europ.  
C: Clearings, fringes

Labiatae (*nom. altr.* Lamiaceae)

- 303 *Clinopodium nepeta* subsp. *glandulosum* (Req.) Govaert H scap, Stenomedit.  
C: Fringes
- 304 *Clinopodium vulgare* subsp. *orientale* Bothmer H scap, E-Stenomedit.  
C: Fringes

- Notes: The Italian Flora Checklists (Conti et al. 2005, Bartolucci et al. 2018) consider the subsp. *arundanum* (Boiss.) Nyman as present in Sardinia, whereas, the Euro+Med PlantBase considers subsp. *arundanum* absent from the island (and the whole Italian peninsula) and that, instead, subsp. *orientale* is present. Our specimens fit well with the diagnostic characters of subsp. *orientale* as described by Bothmer (1967).
- 305 *Glechoma sardoa* (Bég.) Bég. H rept, Endem. Sa  
L: Woods, fringes
- 306 *Lamium maculatum* (L.) L. H scap, Euras.  
U: Forest near forestry headquarters, under *Quercus ilex*  
Notes: according to Arrigoni (2006–2015), this taxon was not found in Sardinia in recent years
- 307 *Lamium purpureum* L. T scap, Euras.  
C: Fringes
- 308 *Lavandula stoechas* L. subsp. *stoechas* NP, Stenomedit.  
C: Garrigues
- 309 *Mentha aquatica* L. H scap, Paleotemp.  
L: Wet meadows
- 310 *Mentha pulegium* L. subsp. *pulegium* H scap, Eurimedit.  
C: Wet meadows, temporary ponds
- 311 *Mentha requienii* Benth. subsp. *requienii* H rept, Endem. Sa-Co  
RR (Su Cantareddu spring): Wet rocks, spring
- 312 *Mentha suaveolens* subsp. *insularis* (Req. ex Gren. & Godr.) Greuter H scap, Endem. Sa-Co-AT-BI  
U (Funtana Arile spring): Fringes
- 313 *Micromeria graeca* (L.) Benth. subsp. *graeca* Ch suffr, Stenomedit.  
C: Garrigues
- 314 *Prunella vulgaris* L. subsp. *vulgaris* H scap, Circumbor.  
C: Wet meadows, fringes, clearings
- 315 *Salvia verbenaca* L. H scap, Medit.-Atl.  
C: Grasslands  
Notes: following the Euro+Med PlantBase, in this taxon we include ecotypes referred to *Salvia clandestina* L.
- 316 *Stachys arvensis* (L.) L. T scap, Europ.  
L: Annual grasslands, pastures
- 317 *Stachys corsica* Pers. H rept, Endem. Sa-Co  
L: Shady rocks and cliffs  
Specimens examined: S'Isfundadu, Anela, 18 June 1965, F. Valsecchi (SS); Badu Addes, Anela, 18 July 1972, B. Corrias, S. Diana, F. Valsecchi (SS)
- 318 *Stachys glutinosa* L. Ch frut, Endem. Sa-Co-AT  
L: Garrigues, rocky habitats
- 319 *Teucrium chamaedrys* L. subsp. *chamaedrys* Ch suffr, Eurimedit.  
U (near the helicopter base): Pastures, grasslands



- 320 *Thymus herba-barona* Loisel. Ch rept, Endem. Sa-Co-Bl  
C: Garrigues

#### Orobanchaceae

- 321 *Orobanche hederæ* Duby T par, Eurimedit.  
C: Woods
- 322 *Orobanche minor* Sm. T par, Paleotemp.  
C: Grasslands, pastures
- 323 *Orobanche nana* (Reut.) Beck T par, Medit.-Macaron.  
L: Grasslands, pastures
- 324 *Orobanche ramosa* L. T par, Paleotemp.  
L: Road sides, pastures
- 325 *Orobanche rapum-genistæ* Thuill. T par, Subatl.  
L: Garrigues with *Genista* sp.
- 326 *Orobanche rigens* Loisel. T par, Endem. Sa-Co  
L: Garrigues with *Genista* sp.
- 327 *Parentucellia latifolia* (L.) Caruel subsp. *latifolia* T scap, Eurimedit.  
C: Pastures
- 328 *Parentucellia viscosa* (L.) Caruel T scap, Medit.-Atl.  
C: Annual grasslands

#### Aquifoliales

##### Aquifoliaceae

- 329 *Ilex aquifolium* L. P caesp, Submedit.-Subatl.  
C: Woods

#### Asterales

##### Campanulaceae

- 330 *Jasione montana* L. H scap, Europ.-Cauc.  
C: Pastures and rocky habitats

##### Compositae (nom. altr. Asteraceae)

- 331 *Achillea ligustica* All. H scap, W-Stenomedit.  
C: Fringes
- 332 *Anthemis arvensis* L. subsp. *arvensis* T scap, Stenomedit.  
C: Pastures
- 333 *Arctium minus* (Hill) Bernh. H bienn, Eurimedit.  
C: Fringes, clearings
- 334 *Bellis annua* L. subsp. *annua* T scap, Stenomedit.  
C: Annual grasslands on wet soils
- 335 *Bellis perennis* L. H ros, Europ.-Cauc.  
C: Wet meadows
- 336 *Bellis sylvestris* Cirillo H ros, Stenomedit.  
L: Perennial grasslands (lower altitudes)

- 337 *Bellium bellidioides* L. H ros, Endem. Sa-Co-Bl-AT  
C: Temporary ponds, wet soils
- 338 *Carlina corymbosa* L. H scap, Stenomedit.  
C: Pastures
- 339 *Carthamus lanatus* L. subsp. *lanatus* T scap, Eurimedit.  
C: Pastures, nitrophilous vegetation near sheep pens
- 340 *Centaurea calcitrapa* L. subsp. *calcitrapa* H bienn, Eurimedit.  
C: Pastures
- 341 *Chamaemelum fuscatum* (Brot.) Vasc. T scap, W-Stenomedit.  
L: Temporary ponds
- 342 *Chondrilla juncea* L. H scap, S-Europ.-S-Sib.  
C: Pastures
- 343 *Cichorium intybus* L. subsp. *intybus* H scap, Paleotemp.  
L: Perennial grasslands
- 344 *Cirsium scabrum* (Poir.) Bonnet & Barratte H scap, SW-Medit.  
L: Fringes, road edges (lower altitudes)
- 345 *Cirsium vulgare* subsp. *silvaticum* (Tausch) Arènes H bienn, Eurimedit.  
C: Fringes, road edges
- 346 *Crepis bellidifolia* Loisel. T scap, W-Stenomedit.  
L: Pastures
- 347 *Crepis leontodontoides* All. H ros, W-Medit.-Mont.  
C: Pastures
- 348 *Crepis vesicaria* L. subsp. *vesicaria* T scap, Submedit.-Subatl.  
C: Pastures
- 349 *Crupina vulgaris* Cass. T scap, S-Sib.-Eurimedit.  
L: Pastures, perennial grasslands
- 350 *Filago gallica* L. T scap, Eurimedit.  
C: Annual grasslands
- 351 *Filago germanica* (L.) Huds. T scap, Paleotemp.  
U (S. Giorgio): Annual grasslands
- 352 *Galactites tomentosus* Moench H bienn, Stenomedit.  
C: Pastures
- 353 *Glebionis coronaria* (L.) Spach. T scap, Stenomedit.  
L: Pastures, annual grasslands (lower altitudes)
- 354 *Helichrysum italicum* subsp. *tyrrhenicum* (Bacch., Brullo et Giusso) Herrando, J.M. Blanco, L. Sáez & Galbany Ch frut., Endem. Sa-Co-Bl  
C: Garrigues  
Notes: for this taxon, we follow Herrando-Moraira et al. (2016)
- 355 *Hyoseris radiata* L. H ros, Stenomedit.  
C: Pastures, meadows
- 356 *Hypochaeris achyrophorus* L. T scap, Stenomedit.  
C: Annual grasslands
- 357 *Hypochaeris cretensis* (L.) Bory & Chaub. H scap, NE-Medit.-Mont.  
L: Dry pastures and rocky habitats

- 358 *Hypochaeris glabra* L. T scap, Eurimedit.  
C: Pastures, meadows
- 359 *Hypochaeris radicata* L. subsp. *radicata* H ros, Europ.-Cauc.  
C: Pastures, meadows
- 360 *Hypochaeris robertia* (Sch. Bip.) Fiori H ros, Endem. Sa-Co-Si-It  
L: Wet rocks and cliffs
- 361 *Lactuca muralis* (L.) Gaertn. H scap, Europ.-Cauc.  
C: Woods, fringes
- 362 *Leontodon tuberosus* L. H ros, Stenomedit.  
C: Grasslands, pastures
- 363 *Pilosella ziziana* (Tausch) F. W. Schultz & Sch. Bip. H scap, Europ. (?)  
L: Grasslands
- 364 *Ptilostemon casabonae* (L.) Greuter H scap, Endem. Sa-Co-AT-Hy  
U (Entrance of the Domain): Road edge
- 365 *Pulicaria odora* (L.) Rchb. H scap, Eurimedit.  
C: Woods, fringes (lower altitude)
- 366 *Reichardia picroides* (L.) Roth H scap, Stenomedit.  
L: Rocky habitats (lower altitudes)
- 367 *Rhagadiolus stellatus* (L.) Gaertn. T scap, Eurimedit.  
C: Annual grasslands
- 368 *Scolymus hispanicus* L. subsp. *hispanicus* H bienn, Eurimedit.  
C: Pastures
- 369 *Senecio vulgaris* L. subsp. *vulgaris* T scap, Eurimedit.  
C: Pastures, ruderal vegetation
- 370 *Sonchus asper* (L.) Hill subsp. *asper* T scap, Euras.  
C: Ruderal vegetation
- 371 *Sonchus oleraceus* L. T scap, Euras.  
C: Ruderal vegetation
- 372 *Silybum marianum* (L.) Gaertn. H bienn, Medit.-Turan.  
C: Ruderal vegetation, pastures
- 373 *Taraxacum* sect. *Erythrosperma* (H. Lindb.) Dahlst. or *Taraxacum* sect. *Scariosa*  
Hand.-Mazz. H ros, Circumbor.  
C: Wet meadows
- 374 *Urospermum dalechampii* (L.) F.W. Schmidt H scap, Eurimedit.  
C: Grasslands

## Dipsacales

### Adoxaceae

- 375 *Sambucus ebulus* L. G rhiz, Eurimedit.  
L: Streams
- 376 *Sambucus nigra* L. P caesp, Europ.-Cauc.  
C: Woods, shrublands



## Caprifoliaceae

- 377 *Dipsacus ferox* Loisel. H bienn, Endem. Sa-Co-Itc  
C: Pastures
- 378 *Valerianella eriocarpa* Desv. T scap, Stenomedit.  
C: Annual grasslands

**Apiales**

## Araliaceae

- 379 *Hedera helix* L. P lian, Eurimedit.  
C: Woods

Umbelliferae (*nom. altr.* Apiaceae)

- 380 *Bunium corydalinum* DC. G bulb, Endem. Sa-Co  
C: Garrigues, rocky habitats
- 381 *Chaerophyllum temulum* L. T scap, Euras.  
L: Woods, fringes
- 382 *Eryngium campestre* L. H scap, Eurimedit.  
C: Pastures
- 383 *Ferula communis* L. subsp. *communis* H scap, S-Eurimedit.  
L: Pastures, clearings (lower altitudes)
- 384 *Oenanthe crocata* L. H scap, Medit.-Atl.  
L: *Alnus glutinosa* woods, streams
- 385 *Oenanthe lisae* Moris H scap, Endem. Sa  
U (Funtana Arile spring): Wet meadows  
Specimen examined: Funtana Arile, Anela, 08 June 1980, B. Corrias, S. Diana (SS)
- 386 *Oenanthe pimpinelloides* L. H scap, Medit.-Atl.  
C: Woods, fringes
- 387 *Sanicula europaea* L. H scap, Paleotemp.  
C: Woods, fringes
- 388 *Smyrniium perfoliatum* subsp. *rotundifolium* (Mill.) Bonnier & Layens  
H bienn, Stenomedit.  
C: Fringes, woods
- 389 *Thapsia garganica* L. subsp. *garganica* H scap, S-Medit.  
C: Pastures, grasslands
- 390 *Torilis africana* Spreng. T scap, Medit.-Macaron.  
C: Pastures, annual grasslands
- 391 *Torilis nodosa* (L.) Gaertn. T scap, Medit.-Turan.  
C: Pastures, annual grasslands

## Ecological and biogeographical analysis of the indigenous flora of Anela

Here we assess the presence in the forest domain of Anela of 391 taxa, belonging to 32 orders and 74 families.

Of the listed taxa, 5 (*Anacamptis longicornu* (Orchidaceae), *Anchusa hybrida* (Boraginaceae), *Chenopodium album* subsp. *album* (Amaranthaceae), *Dactylorhiza insularis* (Orchidaceae), *Scrophularia umbrosa* (Scrophulariaceae)) were not found during our investigation. Excluding these species, then we recorded a total of 386 indigenous taxa within the domain. Two species are new for the Sardinian flora (*Agrostis capillaris*, *Asplenium adiantum-nigrum*) and, for 17 taxa, our findings determine an important enlargement of their known range on the island (*Arrhenatherum elatius* subsp. *sardoum*, *Asplenium foreziense*, *Clinopodium vulgare* subsp. *orientale*, *Colchicum nanum*, *Danthonia decumbens* subsp. *decumbens*, *Euphorbia semiperfoliata*, *Exaculum pusillum*, *Festuca morisiana* subsp. *morisiana*, *Lamium maculatum*, *Mentha requienii* subsp. *requienii*, *Morisia monanthos*, *Poa balbisii*, *Prunus domestica* subsp. *insititia*, *Ranunculus cordiger* subsp. *cordiger*, *Rosa subcanina*, *Veronica verna* subsp. *brevistyla*, *Viola reichenbachiana*).

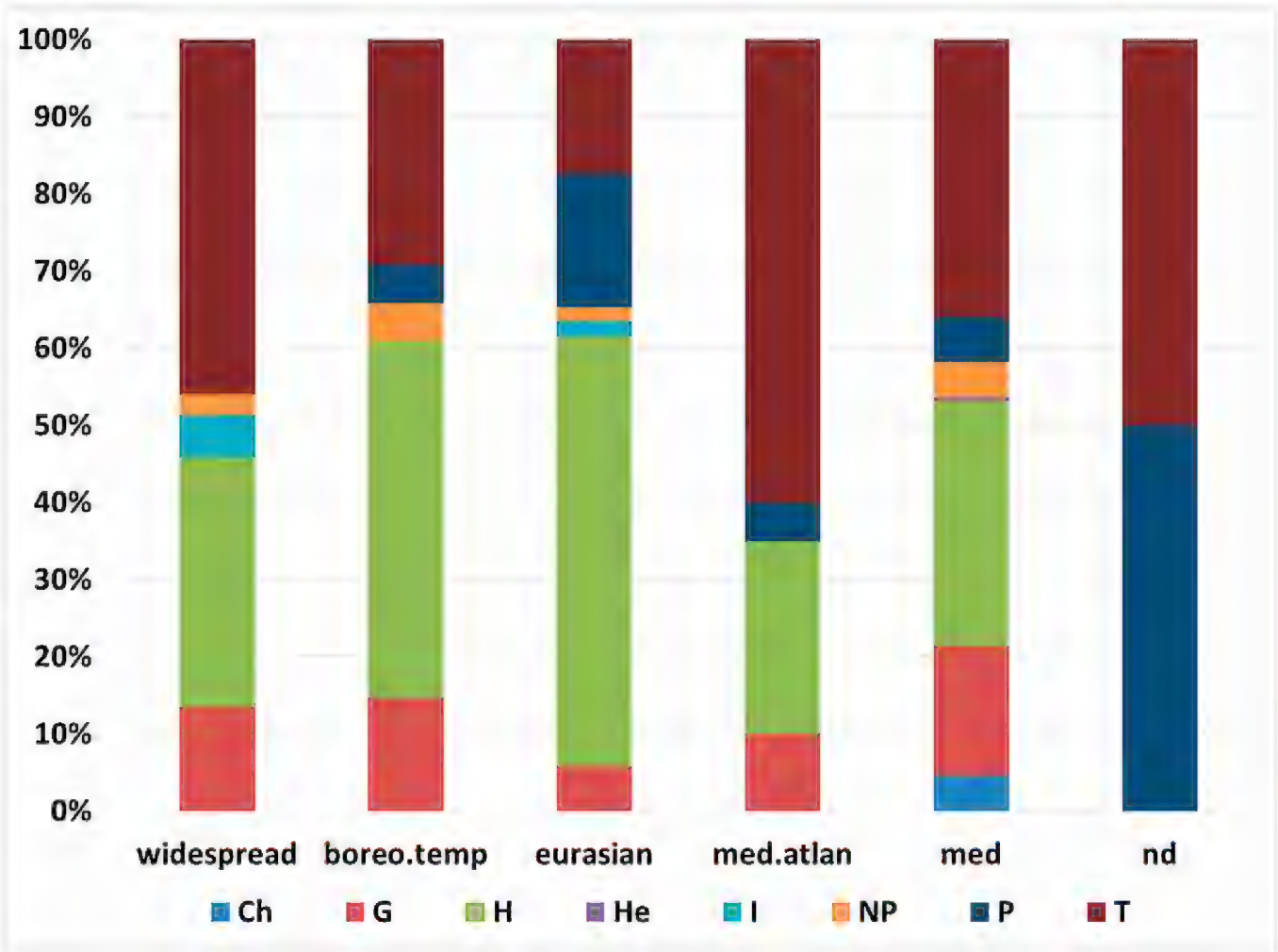
Overall, we found 141 hemicryptophytes (36.1%), 137 therophytes (35.0%), 56 geophytes (14.3%), 27 phanaerophytes (6.9%), 15 nano-phanaerophytes (3.8%), 11 chamaephytes (2.8%), 3 hydrophytes (0.8%), and 1 helophyte (0.3%).

A total of 239 taxa belong to the Mediterranean element (61.1%), 53 are Eurasian *sensu lato* (including the true Eurasian, plus European, Euro-Siberian, Euro-Caucasian and Pontic district: overall 13.6%), 42 are Boreal-Temperate taxa (paleotemperate + circumboreal: 10.7%), 36 are widespread (cosmopolitan, sub-cosmopolitan and subtropical: 9.2%) and 19 are Atlantic (4.9%). We were not able to assign a geographical category to *Prunus domestica* subsp. *insititia*.

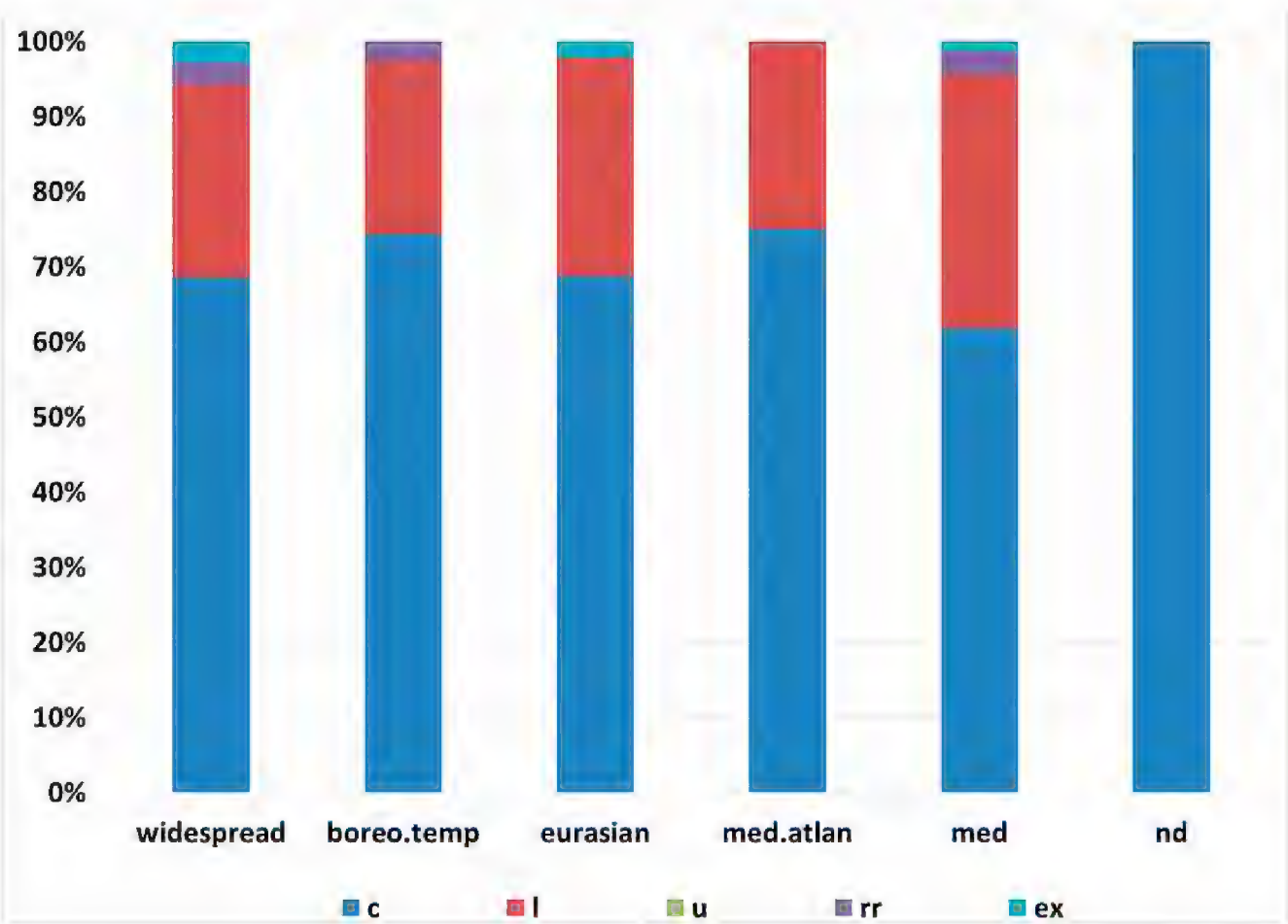
Hemicryptophytes dominate within the Boreal-Temperate and the Eurasian components; annual species prevail within the widespread and the Mediterranean-Atlantic groups. The Mediterranean component hosts similar percentages of annuals and hemicryptophytes (Fig. 2).

The Mediterranean component is dominated by the euri-Mediterranean sub-element (94 taxa, 24.0% of the whole flora), followed by the steno-Mediterranean (77 taxa, 19.7%) and the endemics (45 entities, 11.5%). A total of 23 Mediterranean taxa belonged to other chorotypes (mountain-Mediterranean, Mediterranean-Turanian, Mediterranean-Macaronesian).

The endemic component of the flora of Anela is dominated by those of the Sardinian-Corsican biogeographic province (*sensu* Bacchetta et al. 2012) accounting for 28 taxa (endemics *sensu stricto*, 7.4%), of which 19 taxa are Sardinian-Corsican (42.2% of the endemic component), followed by Sardinian entities (5, 11.1%) and those present on Sardinia, Corsica and the Tuscan Archipelago (4, 8.9%). Tyrrhenian or Hercynian endemics (those present in Sardinia, Corsica, Tuscan Archipelago, the Balearic and Hyeres Islands and Sicily) account 12 (26.7%) and, finally, 11.1% is constituted by 5 entities with larger ranges including some continental areas (Sardinia and northern Africa or Sardinia and Italy).



**Figure 2.** Percentage of biological types for each chorologic element detected in the vascular flora of Anela (390 taxa). boreo.temp = Boreal-temperate taxa; med.atlan = Mediterranean-Atlantic taxa; med = Mediterranean; nd = not determined.



**Figure 3.** Percentage of abundance categories for each chorologic element detected in the vascular flora of Anela (390 taxa). c = common; l = localized; u = uncommon; rr = range restricted; ex = extinct. ; boreo.temp = Boreal-temperate taxa; med.atlan = Mediterranean-Atlantic taxa; med = Mediterranean; nd = not determined.



On the basis of our criteria, 241 taxa (61.6%) can be considered common at the local level, 113 (28.9%) are localised, 23 (5.9%) are uncommon, 9 (2.3%) are range restricted and 5 (1.3%) are locally extinct in the last 50 years. Common taxa are the dominant category in all the geographic groups, whereas range restricted taxa are found only in the widespread, Boreal-Temperate and the Mediterranean groups (Fig. 3).

A total of 176 out of 387 taxa were found mainly in grasslands habitats (45.5%) including dry pastures (61 taxa), annual and perennial grasslands (52 and 31 taxa, respectively) and wet pastures and meadows (32 taxa). Woodland habitats hosted 97 taxa (25.1%), comprising woods (57 taxa), fringes and clearings (30 taxa) and shrubs (10 taxa). Wet habitats (including *Alnus glutinosa* woods, springs, temporary ponds, ditches, muds, streams) hosted 53 taxa (13.7%). Rocky habitats (cliffs, rocks, screes) harbour 24 taxa (6.2%), then the garrigues hosted 21 taxa (5.4%) and finally the anthropogenic habitats (ruderal vegetation, buildings, walls, trampled sites, road edges) were the main habitat for 15 taxa (3.9%).

## Discussion

### Biogeographical description of the mountain

Our research discovered a high species density at the study area (30.6 taxa km<sup>-2</sup>), that is one of the highest ever documented in the Sardinian mountain floras (Table 1). Even if there is a clear inverse relationship between the area investigated and species' density, we should note that, for areas having a comparable surface (~ 10 km<sup>2</sup>), the floristic density recorded at our study area is second only to the Mt. Gonare complex (Camarda 1984a, 1984b). It is noteworthy that the summit area of Sardinia (> 1500 m a.s.l.), having a surface of 16.8 km<sup>2</sup>, hosts "only" 214 taxa of which 66 are considered endemics (Arrigoni and Camarda 2015). So we can argue that areas at the edge between the Mediterranean and the temperate bioclimates, like Foresta Demaniale Anela and Mt. Gonare, host floristic components from both the two bioclimatic – biogeographic regions, having therefore more abundant floras than areas located in coastal or summit zones.

The hemicryptophytes/therophytes (H/T) ratio, as previously noted by Arrigoni and Camarda (2015), underlines the co-presence of two main elements, the perennial and the annual herbs, having very different life-cycles and summing 71.1% of our flora. The H/T ratio, that in Sardinia peaks at 2.5 at the summit of Gennargentu (Arrigoni and Camarda 2015), but decreases to 0.74 as the regional average, is at Anela 1.03. Limestone mountains like Mt. Albo, with a karst geology and consequently a pronounced summer drought, have a H/T ratio even lower than the regional average, whereas mountain complexes with impermeable substrates (plutonic, volcanic, metamorphic) approaching 1000 m a.s.l. have a H/T ratio ~ 1 gradually increasing with elevation (Table 1). This means that at 1000 m a.s.l., the co-presence of two large groups of non-woody plants, having an annual or perennial life cycle, has been detected: the annuals have a greater prevalence at lower altitudes, the perennials at higher altitudes and their ratio ~ 1 at 1000 m a.s.l. underlines the transition character of this altimetric level in Sardinia.

**Table 1.** Synthetic data on mountain floras from Sardinia and the regional flora, based on different sources (see notes below).

Site	Altitudinal interval	Area (km <sup>2</sup> )	No. taxa	Taxa / km <sup>2</sup>	H/T	No. endemics	% endemics	Source
Anela forest domain	600–1158	12.8	391	30.6	1.03	45	11.5	This work
Gennargentu	1500–1834	16.8	214	12.7	2.5	66	30.8	Arrigoni and Camarda 2015
Gennargentu	1000–1834	240	675	2.8	1.25	105	15.6	Arrigoni and Camarda 2015
Gennargentu	1000–1834	500	897 <sup>†</sup>	1.8	1.03 <sup>‡</sup>	n.d.	28 <sup>§</sup>	Bacchetta et al. 2013
Supramontes	0–1463	335	n.d.	n.d.	n.d.	138	30 <sup>§</sup>	Fenu et al. 2010
Mt. Albo	900–1127	68	659	9.7	0.61	48	7.3	Camarda 1984a
Mt. Gonare	538–1083	10	520	52	0.85	23	4.4	Camarda 1984b
Mt. Limbara	160–1359	166.24	923	5.5	0.75	80	8.7	Calvia and Ruggero unpublished
Mt. Limbara	800–1359	49.46	687	13.9	0.84	72	10.5	Calvia and Ruggero unpublished
Mt. Limbara	500–1359	n.r.	506	n.d.	1.18	55	10.9	Veri and Bruno 1974
Sardinia	0–1834	24090	2028	0.084	0.70	n.d.	7.1	Pignatti 1995
Sardinia	0–1834	24090	2400	0.099	n.d.	n.d.	n.d.	Arrigoni (2006–15)
Sardinia	0–1834	24090	2408 <sup>‡</sup>	0.1	0.74 <sup>‡</sup>	290 <sup>#</sup>	12	Various (see notes)
Sardinia	0–1834	24090	2149	0.09	n.r.	290	13.5	Médail 2017, table 2
Sardinia	0–1834	24090	2301	0.095	n.r.	331	14.4	Bartolucci et al. 2018

<sup>†</sup>Bacchetta et al. (2013) list 948 entities, including 10 varieties, 3 hybrids and 38 aliens: here we therefore consider 897 native taxa; <sup>‡</sup>calculated by Arrigoni and Camarda 2015; <sup>§</sup>Cañadas et al. 2014; <sup>‡</sup>Conti et al. 2005; <sup>‡</sup>Arrigoni and Camarda 2015; <sup>#</sup>Fenu et al. 2014; n.r. not reported; n.d. not determined.

Important differences with the regional (Sardinian) value (Pignatti 1995) have also been detected for the Mediterranean floristic component, particularly the steno-Mediterranean taxa having a 28.9% regional percentage and 19.7% at the Anela forest domain; contrarily, the euri-Mediterranean component has 16.1% regional average but increases to 24% at our study area, the same percentage (24.3%) reached by the sum of the Boreal-Temperate and the Eurasian floristic components. Whereas lower altitude floras have a dominant steno-Mediterranean component and the floras at the summit of Mediterranean mountains show the prevalence of southern-European and Mediterranean orophytes and narrow endemics (Cañadas et al. 2014; Arrigoni and Camarda 2015), our flora is a good example of transition areas, having the 80% of taxa quite equally distributed amongst steno-Mediterranean, euri-Mediterranean, Boreal-Temperate and Eurasian and the endemic contingents. High species density, H/T ratio ~ 1, balance amongst different chorologic groups and endemic percentage ~ 10% can be considered characteristic features of mountain areas at the transition between the Mediterranean and the temperate bioclimates.

The composition of the flora of the Forest Domain of Anela is also peculiar because it is one of the few examples, not only in Sardinia but in the whole Mediterranean area, with no native Gymnosperms. Junipers (*Juniperus phoenicea* subsp. *turbinata* (Guss.) Nym. and *J. oxycedrus* subsp. *macrocarpa* (Sibth. & Sm.) Neilr.) in NW Sardinia are mainly confined in coastal areas (Farris et al. 2017), but Yew (*Taxus baccata* L.) and Prikly Juniper (*Juniperus oxycedrus* L. subsp. *oxycedrus*) are usually present in high hills

and mountains. However junipers are not present in NW Sardinia inland areas (Farris et al. 2017), but the Yew is occurring in all the massifs and mountain ranges, including the two forest domains bordering Anela, the Fiorentini Forest Domain to the east (municipality of Bultei) and the Mt. Pisanu Forest Domain to the west (municipality of Bono, see Farris and Filigheddu 2008). The total absence of Gymnosperms in the native flora of the Anela forest domain is therefore surprising, most probably anomalous and it seems likely to be linked to the management history of the area rather than a natural pattern (Sechi and Falchi 2013).

Despite the fact that in 2004 (last forest census) 90.4% of the domain area was covered by forest or shrub communities (Sechi and Falchi 2013), it is striking that the 45% of the detected taxa were linked mainly to herbaceous habitats (annual and perennial grasslands, dry and wet pastures and meadows), already described for their peculiar and original floristic composition (Farris et al. 2013). Traditional grazing, particularly ovine pastoralism characterised by low flock density and transhumance, has been proven to be beneficial for the plant biodiversity of Mediterranean silvo-pastoral systems, whereas abandonment is detrimental even at short temporal scales (Farris et al. 2010a). The forest domain of Anela is a typical case where ovine stocks had a dramatic decrease in a short period: between 1990 and 2007, a decrease from 0.77 sheep ha<sup>-1</sup> to 0.13 sheep ha<sup>-1</sup> has been recorded (-83%, Farris et al. 2010a), whereas wood and shrub communities linked to potential natural vegetation (*sensu* Farris et al. 2010b) are recovering very fast, following a trend common to all Italy (Falcucci et al. 2007) and particularly to Sardinia (Puddu et al. 2012).

### Conservation issues of this Flora

Even if rarity is not always linked to threat (de Lange and Norton 1998, Bacchetta et al. 2012), it is an important feature to consider when setting conservation priorities within long lists of taxa (Bacchetta et al. 2012, Le Berre et al. 2018), as in the case of the flora of the Anela forest domain. Additionally, 14 out of 32 uncommon and range-restricted taxa found in this flora are linked to wet habitats: some belong to the Mediterranean and endemic contingents (*Cerastium ligusticum* subsp. *palustre*, *Exaculum pusillum*, *Isoetes hystrix*, *Mentha suaveolens* subsp. *insularis*, *Mentha requienii* subsp. *requienii*, *Morisia monanthos*, *Oenanthe lisae*), others to the Eurasian and Boreal-Temperate contingents (*Struthiopteris spicant*, *Carex remota*, *Iris pseudacorus*, *Solanum dulcamara*, *Spiranthes spiralis*). Those habitats are supposed to be highly vulnerable (Filipe et al. 2013), as changes in land use and modification of water balance (because of climate change or human use) are amongst the most important threats to wetlands. Moreover, little is known about the resilience of associated plant communities, a threat increased by the high spatial isolation of such places within a Mediterranean context. At the study site, we detected several species having a contraction of range or local extinctions caused by the capture of surface or underground water for human use, as for example *Struthiopteris spicant*, *Cerastium ligusticum* subsp. *palustre*, *Mentha requienii*



subsp. *requienii* and the localized fern *Osmunda regalis* for which we documented a local decrease > 50% in the last 20 years. Other species had a decrease directly caused by drainage of temporary ponds (*Exaculum pusillum*, *Isoetes hystrix*, *Morisia monanthos*). Water management in a climatic changing scenario is and will increasingly be a key issue for the conservation of biodiversity in the Mediterranean basin (Casazza et al. 2014), a climatic change hotspot at the global scale (Giorgi 2006, Giorgi and Lionello 2008), where wet habitats and the species linked are amongst the most threatened (Ghosn et al. 2010, Pérez-Luque et al. 2015).

The 5 taxa, locally extinct, have no relationship with a particular habitat or human use from which they are (were) dependent for their survival in the area, with the exception of *Chenopodium album* whose disappearance could be explained with the above-mentioned abandonment of pastoral activities, as it is a nitrophilous species. Their disappearance in the last decades, inferred from herbarium records, can be therefore a normal turnover in the composition of the local indigenous flora or an artifact derived from our sampling method (in the sense that these taxa are maybe still present in the area but we were not able to find them during our monthly sampling excursions).

Amongst the flora we inventoried, it is worth mentioning that several populations represent peripheral populations regarding the overall distribution of the taxa. First, a group of uncommon or range restricted species in the domain, are common plants in the Mediterranean bioclimate areas of Sardinia and sometimes in the whole basin. They are here confined to warm niches in the mountain area under study (*Anemone hortensis*, *Arbutus unedo*, *Arisarum vulgare*, *Arum pictum*, *Celtis australis*, *Ficus carica*, *Ptilostemon casabonae*), places relatively scattered through this mountain landscape. Oppositely, several Boreal-Temperate and Eurasian taxa confined in this sub-Mediterranean bioclimate island represent peripheral populations isolated sometimes by over 1000 km of their northern range. Those constitute rear edge populations (Hampe and Petit 2005) which may contain unique genetic variation, inherited from ancient species distribution and particular ecological conditions. These two contrasted situations have been highlighted several times within the Mediterranean flora (Lavergne et al. 2005, 2006) and are characteristic of those climatic transition areas. These plants all share the characteristic of occurring as fragmented, disjunct and often highly isolated populations, which restrain gene flow with central population (Pironon et al. 2017) and enhance amongst-population differentiation (Papuga et al. 2018). Thus, the relative isolation associated with potentially marginal ecological conditions highlight their evolutionary potential (Thompson 1999, Anacker and Strauss 2014), as it has recently been shown in Sardinia and Corsica for some marginal and peripheral populations of *Cyclamen repandum* (Thompson et al. 2018). Additionally, these groups of taxa are often found in different macro-habitats which have very different links with human activities, therefore leading to different threats and management issues (Lavergne et al. 2006). Thus, conservation policies need to integrate such complex entities within their framework (Lesica and Allendorf 1995, Brunnell et al. 2004, Leppig and White 2006). Finally, those transition areas also contain numerous endemics, which render those places original and of high value for conservation.

Even if biodiversity hot-spots definition at multiple spatial scales is commonly based on the presence, density and distribution of endemic taxa (Myers et al. 2000, Cañadas et al. 2014), the data here presented support that other parameters should also be taken into account to more precisely define priority areas for conservation, as taxonomic complexity (Ennos et al. 2005) of floras and evolutionary potential of populations (Thompson et al. 2010), detected within continuous schemes of biodiversity monitoring (Marignani et al. 2014). This is particularly urgent in southern European mountains, whose biodiversity is threatened by both climate and land use changes (Bravo et al. 2008, Benito et al. 2011, Pauli et al. 2012, Vogiatzakis et al. 2016).

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